Alternative Scenarios and Land-cover Change:
Examples Using Nutrient Export

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Alternative Scenario: use “forecast” of future regional urbanization pattern to distinguish between (working definitions) of risk and vulnerability.

Land-cover change: link land-cover change, nutrient export and vulnerability using more traditional EPA endpoints.

Nutrient Export Model

Land-Cover	WS (ha)	N/P	# of Obs.	Min	Q_{25}	Q_{50}	Q_{75}	Max
Agriculture	**40-8000**	**N**	**30**	**2.1**	**6.6**	**11.1**	**20.3**	**53.2**
Urban	**4-4800**	**N**	**19**	**1.5**	**4.0**	**6.5**	**12.8**	**38.5**
Forest	**7-47000**	**N**	**21**	**1.4**	**1.9**	**2.5**	**3.3**	**7.3**
Agriculture	**40-8000**	**P**	**27**	**0.08**	**0.49**	**0.91**	**1.34**	**5.40**
Urban	**4-4800**	**P**	**24**	**0.19**	**0.69**	**1.10**	**3.39**	**6.23**
Forest	**7-47000**	**P**	**62**	**0.01**	**0.04**	**0.08**	**0.22**	**0.83**

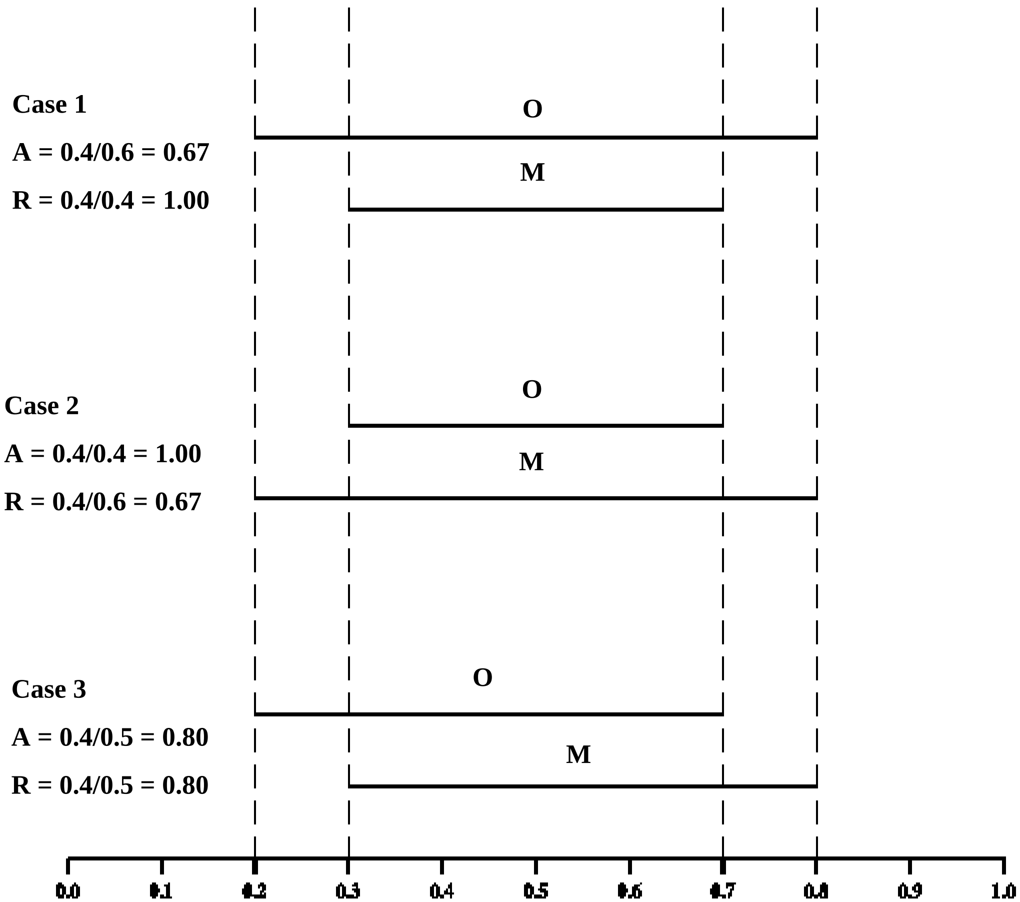
		Forest		Agriculture		Urban	
Distribution		**KD**	**Pr>D**	**KD**	**Pr>D**	**KD**	**Pr>D**
Normal	**N**	**0.2773**	**<0.01**	**0.2030**	**<0.01**	**0.2358**	**<0.01**
	P	**0.2205**	**<0.01**	**0.2952**	**<0.01**	**0.2411**	**<0.01**
Lognormal	***N***	***0.1260***	***>0.15***	***0.0769***	***>0.15***	***0.1183***	***>0.15***
	P	***0.0907***	***>0.15***	***0.1289***	***>0.15***	***0.1272***	***>0.15***
Exponential	**N**	**0.3512**	**<0.01**	**0.1236**	**>0.15**	**0.1479**	**>0.15**
	P	**0.1264**	**0.091**	**0.1651**	**>0.15**	**0.1241**	**>0.15**

Land-cover		Mu	Sigma
Agriculture	**N**	**2.41**	**0.92**
	P	**-0.22**	**1.04**
Urban	**N**	**1.90**	**0.91**
	P	**0.23**	**0.99**
Forest	**N**	**1.02**	**0.51**
	P	**-2.35**	**1.11**

$$N, P = \sum_{i}^{n} (C_i * \mathrm{A_i})$$

Watershed Nutrient Export Risk

--- Model Performance ---



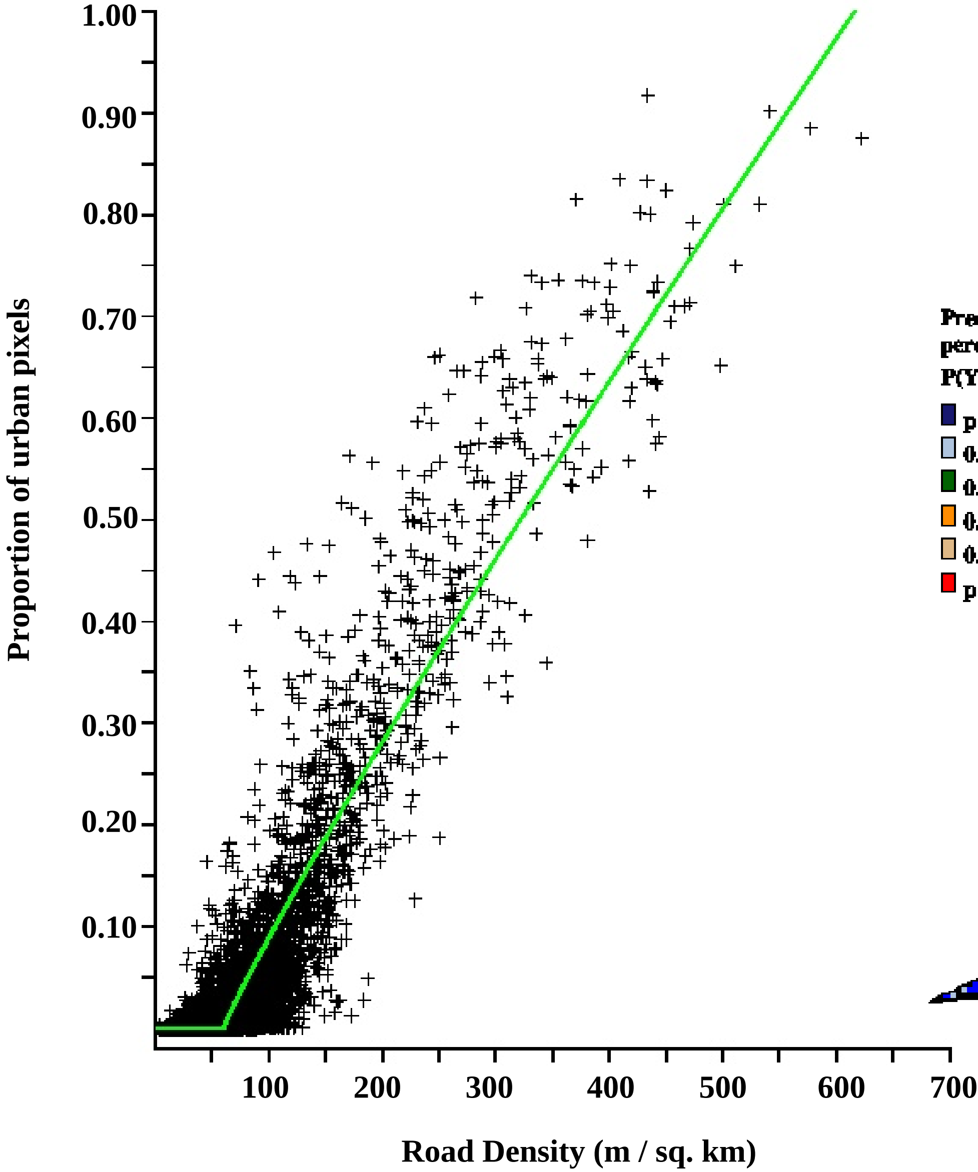
Comparison

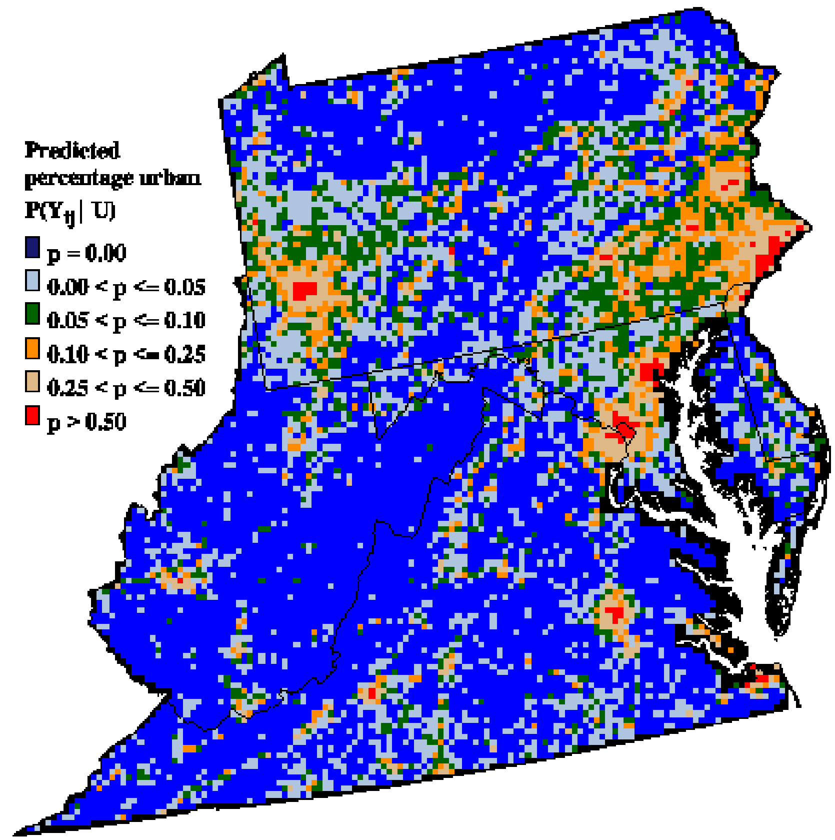
Nitrogen	Adequacy	Reliability
Obs. Vs. Q_{25}-Q_{75}	0.51	1.00
Obs. Vs. Q_{05}-Q_{95}	0.79	1.00
Obs. Vs. Q_{0}-Q_{100}	0.98	0.97
Phosphorus		
Obs. Vs. Q_{25}-Q_{75}	0.67	0.97
Obs. Vs. Q_{05}-Q_{95}	0.83	0.81
Obs. Vs. Q_{0}-Q_{100}	0.97	0.73

Model performance measures from Gardner & Urban (in press).

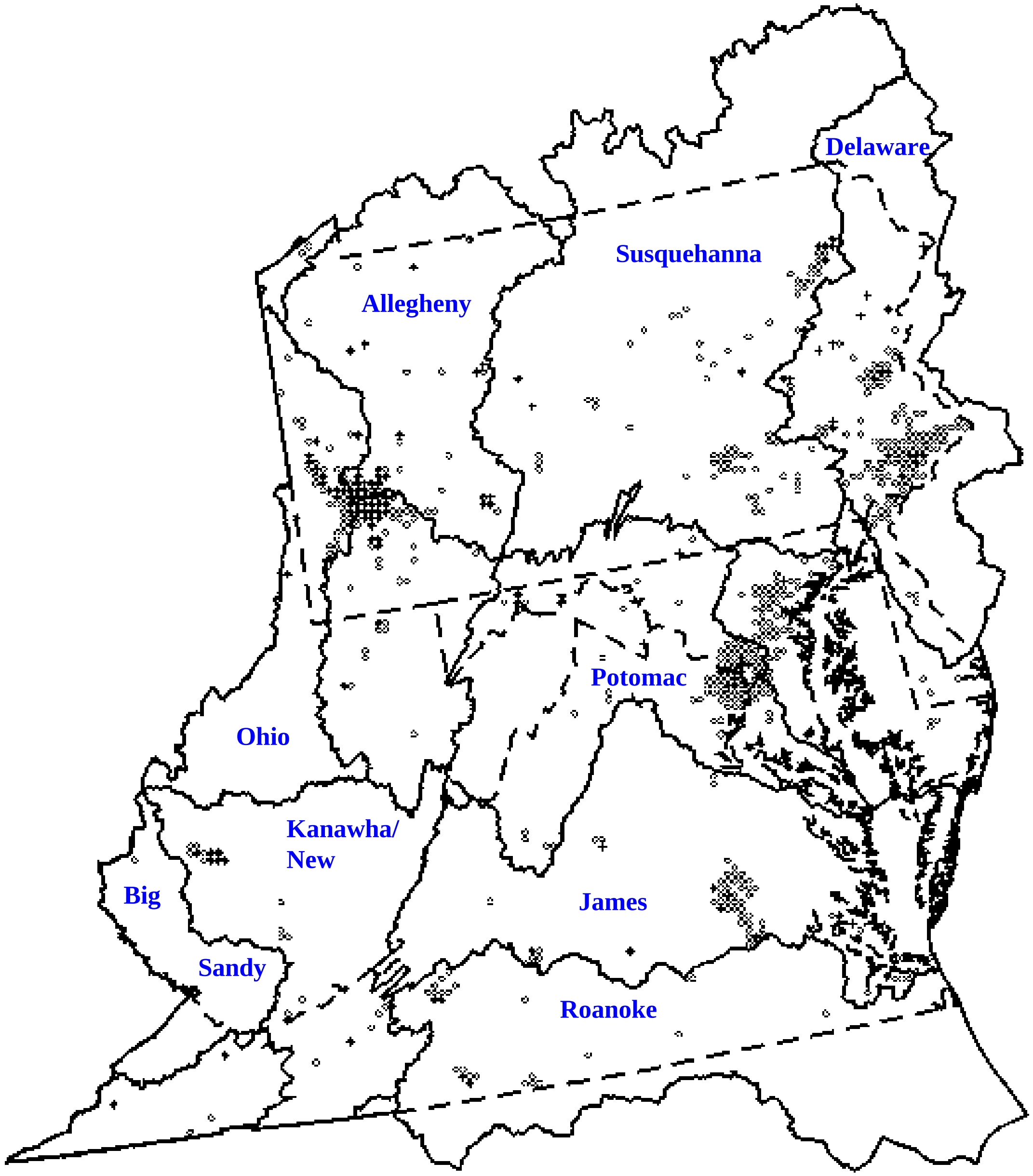
Observed data from Jones et al. (2001)

“Forecasting” Regional Changes in Nutrient Export Risk





Future Scenario of Nutrient Export Risk



◇ P risk increase
≥ 4.0%

\+ N risk increase
≥ 4.5%

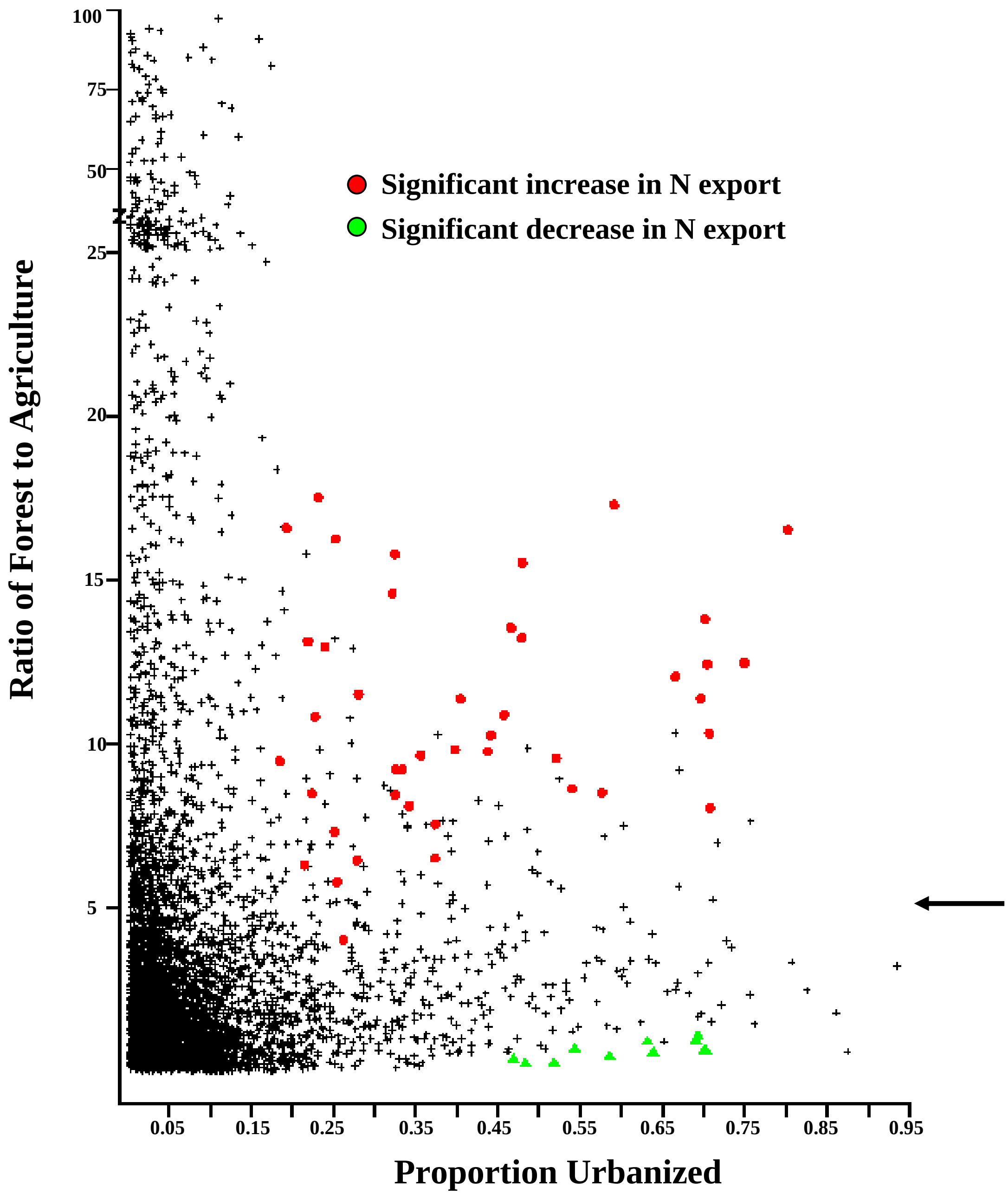
Significance of 4.0 & 4.5% Thresholds

Sum of stochastic "error" in risk model and prediction error in forecasting model

Results

- 131 localities with significant increases in N Risk.
- 606 localities with significant increases in P Risk.
- N risk primarily in Ohio basin
- P risk primarily in Atlantic drainage

State Space Analysis -- "Forecasted" Changes



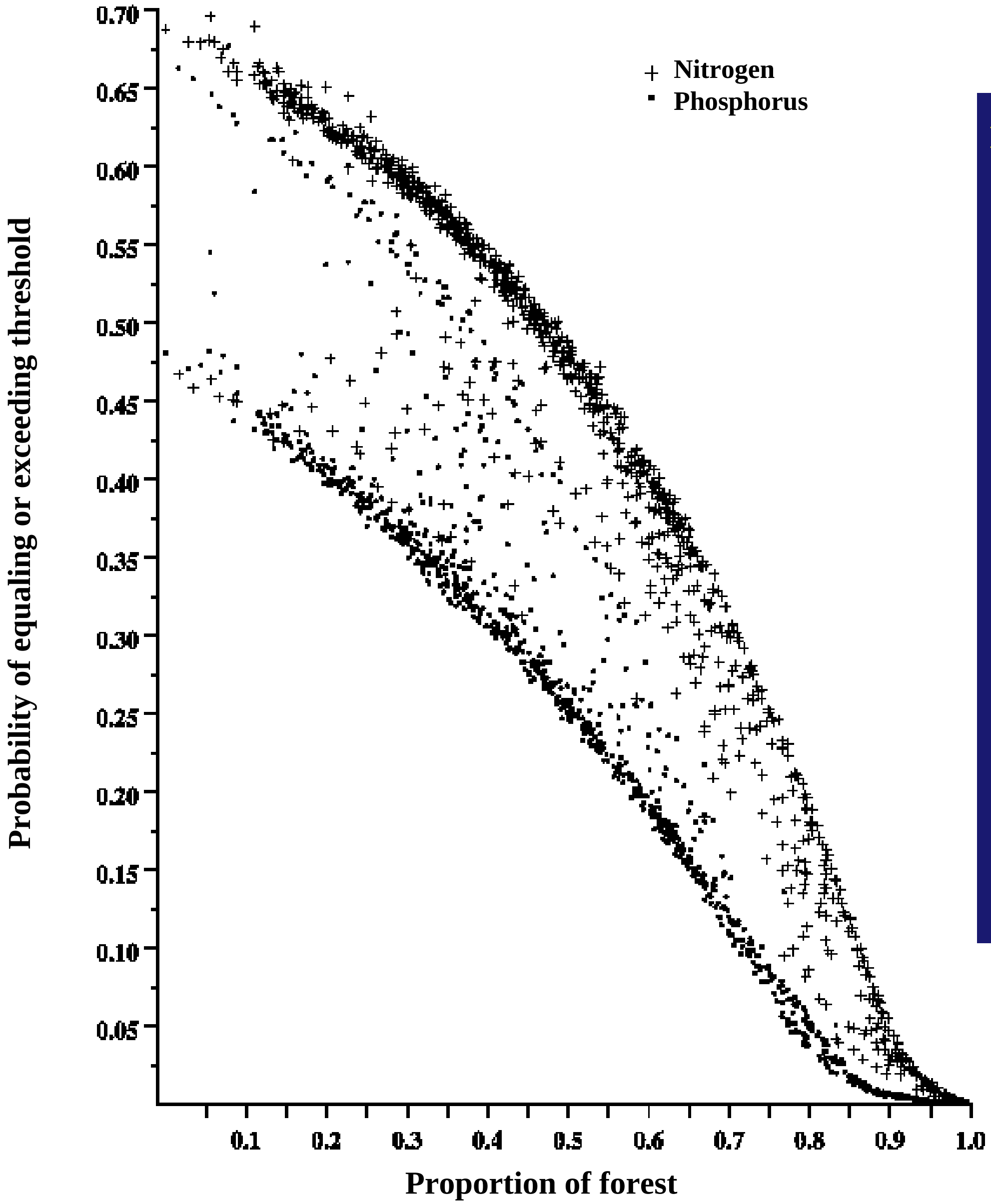
Terms **(working definitions)**

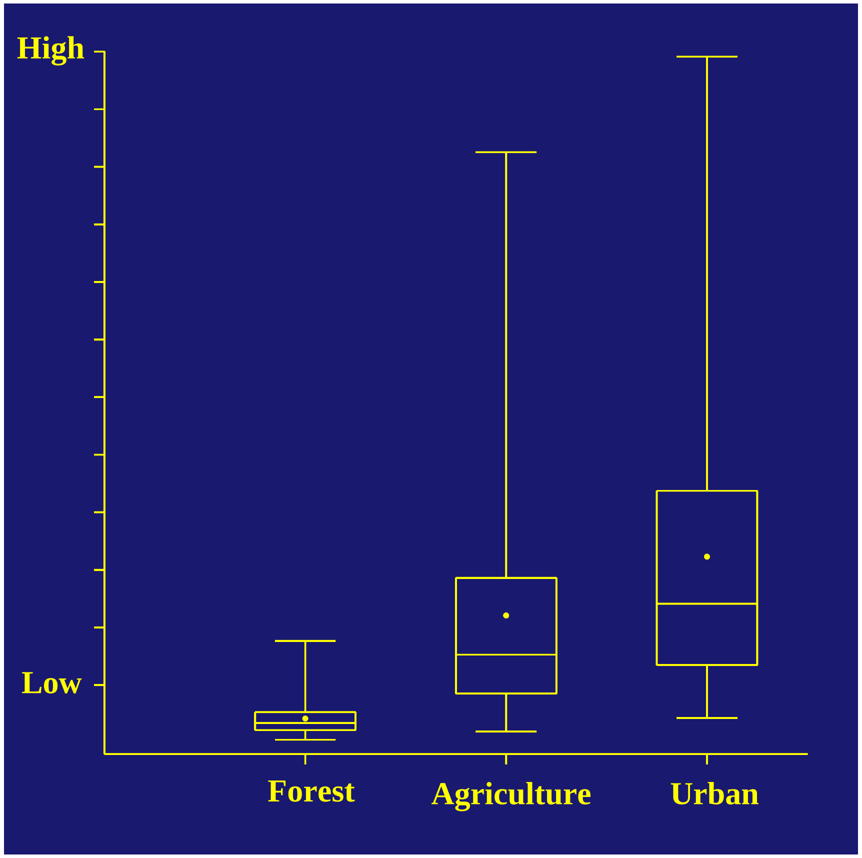
Risk – likelihood of an event.

Vulnerability – changes in risk that exceed model error terms.

Vulnerable areas had at least 5x more forest than agriculture and an 20% increase in urbanization.

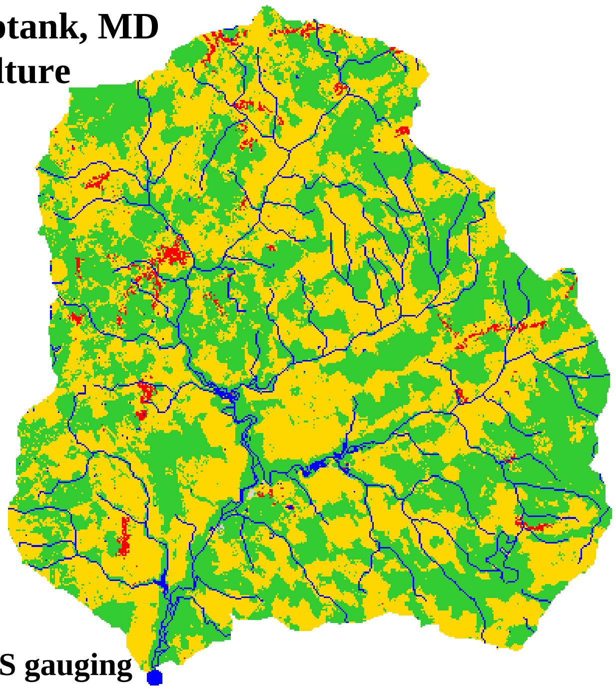
Nutrient Export and Land-cover Change





Why Is Variance Important?

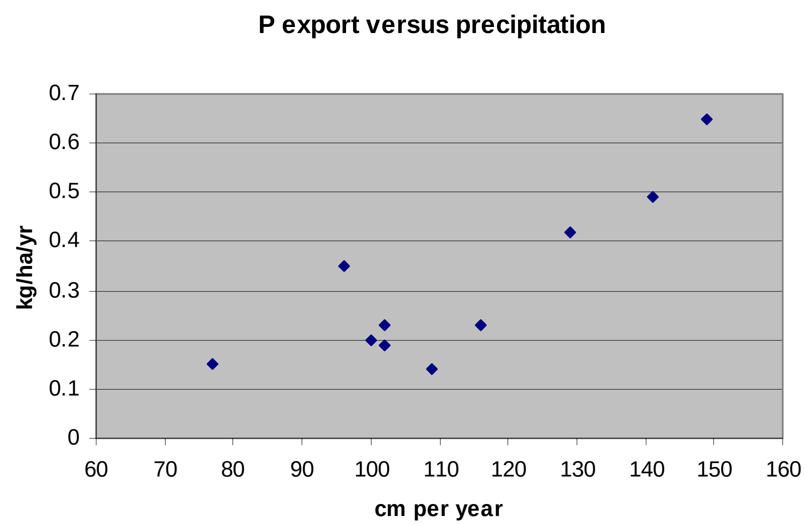
Upper Choptank, MD
49% agriculture
49% forest
1% urban



USGS gauging station 01491000

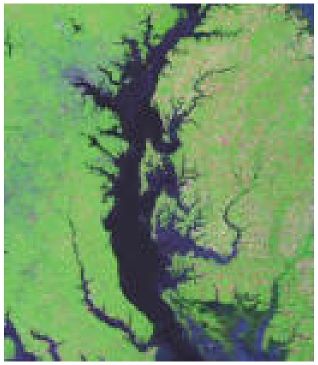
Date	Precipitation (cm/yr)	N export (kg/ha/yr)	P export (kg/ha/yr)
1981	102	3.21	0.23
1982	102	5.06	0.19
1983	129	**8.17**	0.42
1984	141	**11.50**	**0.49**
1985	109	2.89	0.14
1986	77	5.09	0.15
1987	100	5.77	0.20
1988	96	3.30	0.35
1989	149	**9.44**	**0.65**
1990	116	**7.42**	0.23

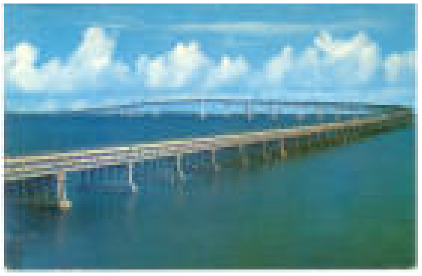
Fisher et al. 1998. ; Linker et al. 1996



An increase in variance is an increase in sensitivity to outside factors; outside factors are more difficult to control, making environmental management more difficult.

Pfiesteria





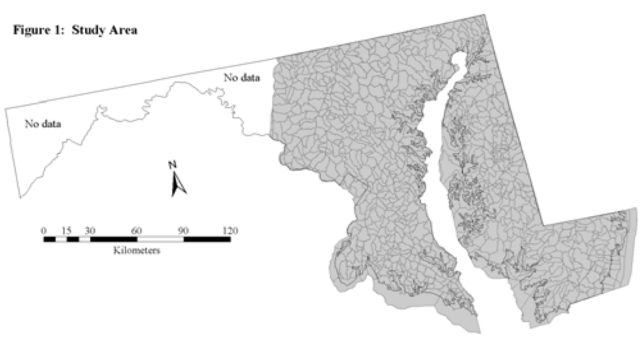
The toxic dinoflagellate, *Pfiesteria piscicida*, has been implicated as the primary causative agent of major fish kills and fish disease events in many Atlantic and Gulf Coast states. Many experiments in lab and field indicate that human influences (e.g., excessive nutrient enrichment) have slowly shifted the environment to encourage *Pfiesteria*'s fish-killing activity. Fish kills caused by *P. piscicida* usually occur in the warmest part of the year, and often precede low dissolved oxygen levels in the estuaries.

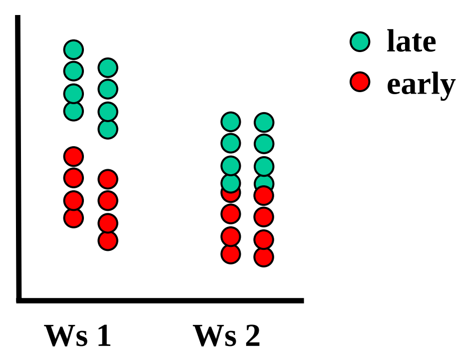
Source: http://www. pfiesteria.org/pfiesteria/index.html

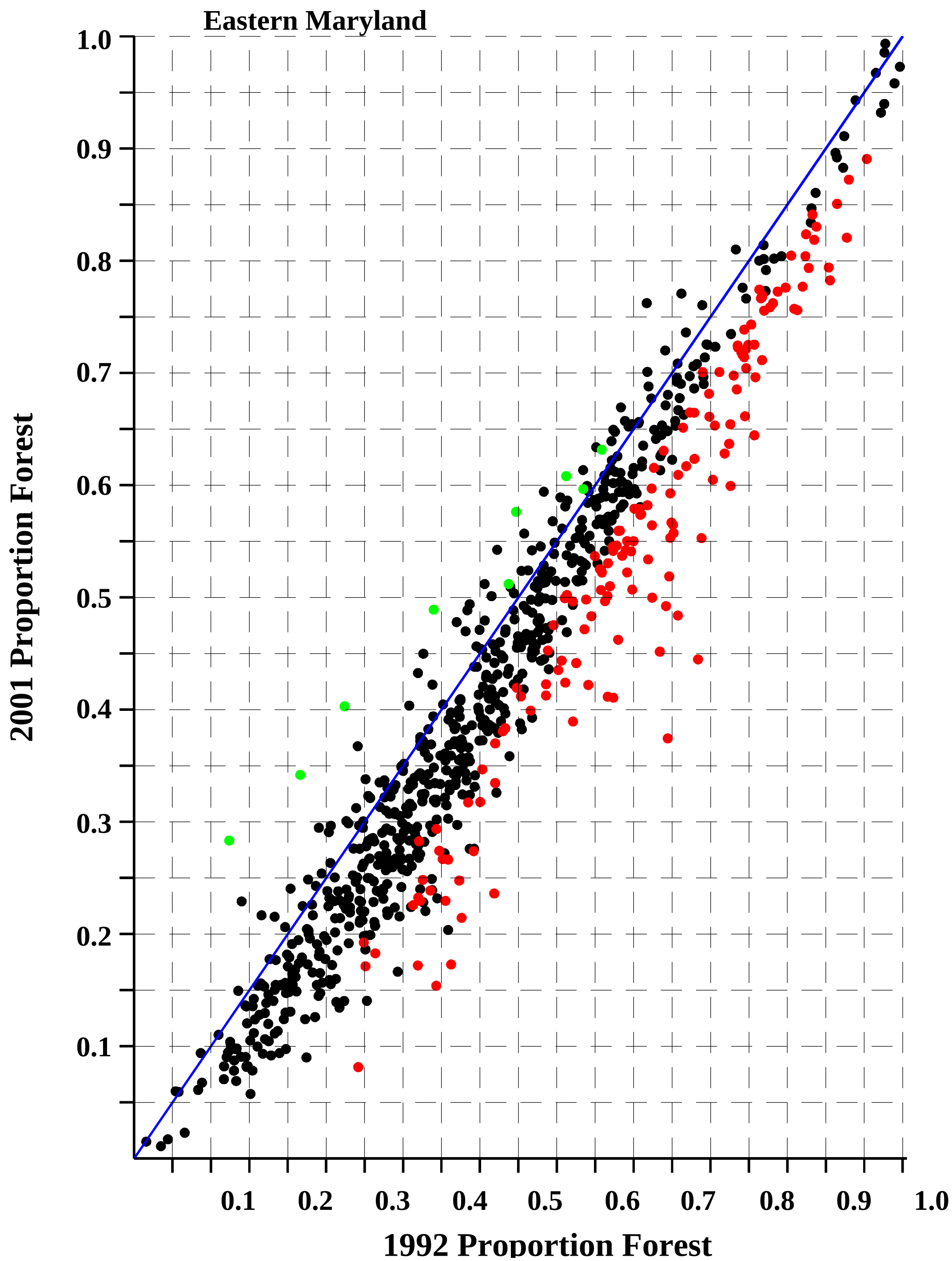
Center for Applied Aquatic Ecology, NC State University

Land-cover Change on N & P Export Variance

1. Compile proportions of forest, agriculture, and urban by watershed for early- and late-date land-cover data.
2. Run N and P export simulations models (by watershed) on temporal land-cover data (estimate mean & variance [1000 obs/ws/date]).
3. Repeat simulations 150 times (per watershed, per date) to generate confidence intervals for means and variances).
4. Compare confidence intervals – significance declared when there was a positive difference (a gap) between mean <u>and</u> variance ranges over time.



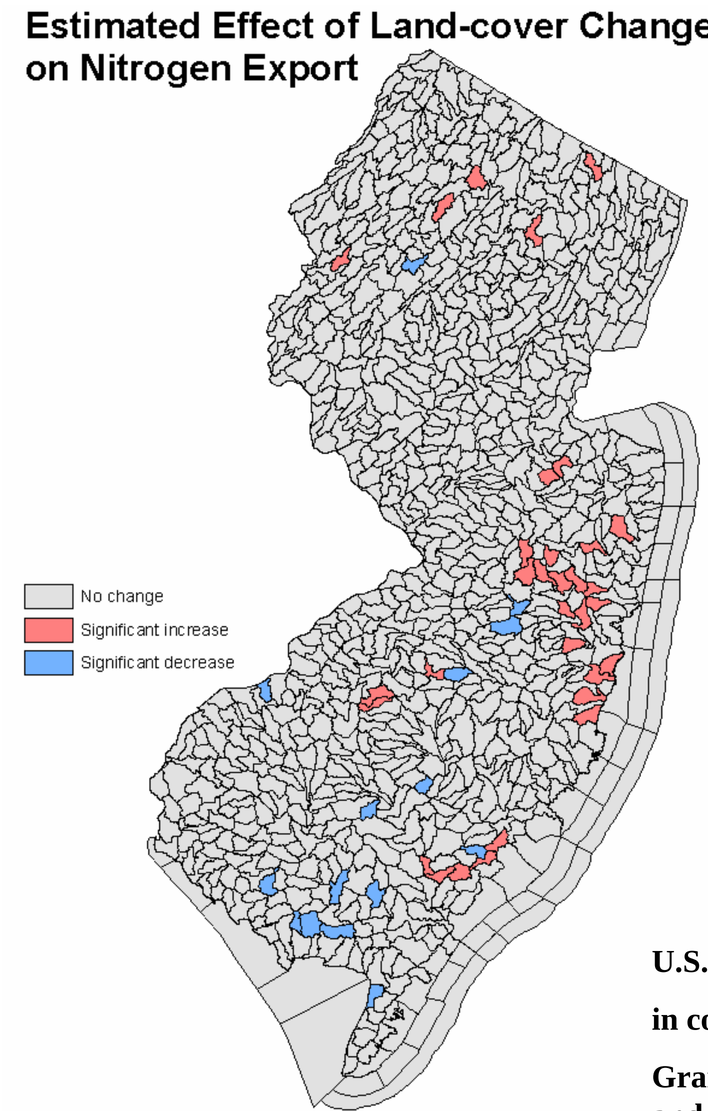


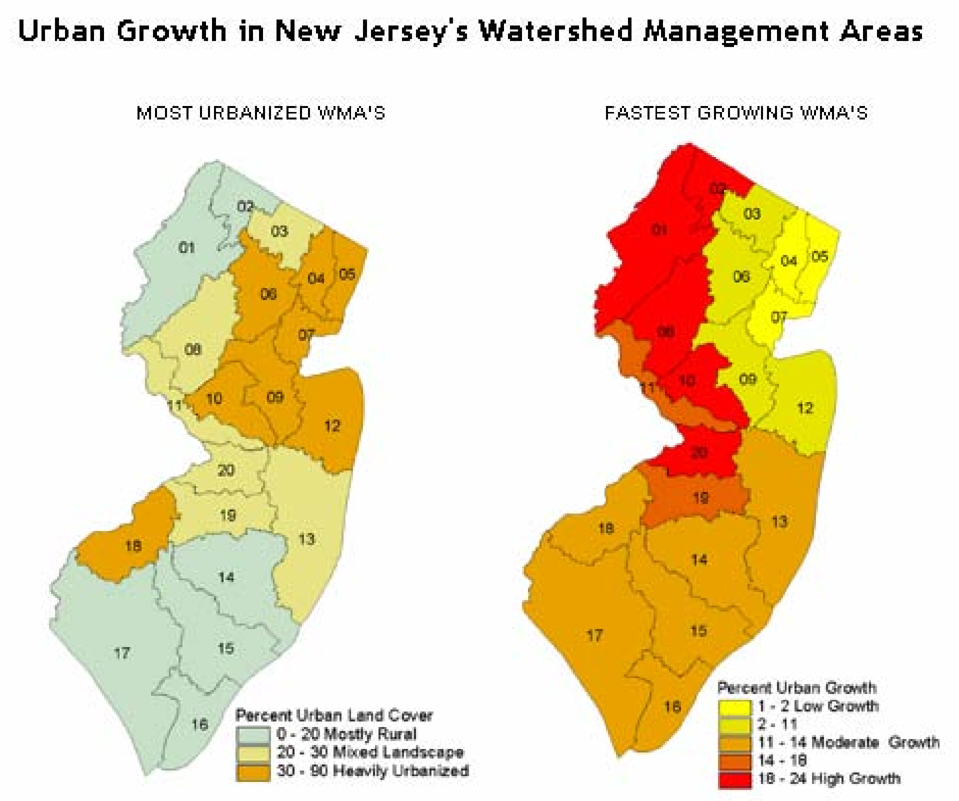


Changes in Nitrogen Export

- Significant increases in export mean and variance for 143 of 812 watersheds.
- Average percentage forest loss was 11% for watersheds with significant increase in variance.
- Amount of forest loss required to significantly change variance increased as percentage forest decreased.
- Watersheds with higher proportions of forest (e.g., > 70%) are more vulnerable to increased nutrient export than watersheds with less forest?

Land-cover Change & N Export Variance -- New Jersey





U.S. EPA, Landscape Ecology Branch

in cooperation with

Grant F. Walton Centre for Remote Sensing and Spatial Analysis, Rutgers University

Summary

Vulnerability distinguished from risk by means of statistical significance tests.

Alternative scenario: vulnerability = change in risk > accumulated model error.

Land-cover change: vulnerability = complete separation of “confidence intervals.”

Spatial patterns of vulnerability

Higher P vulnerability for Ohio and higher N for Atlantic (Alternative Scenario)

Increasing vulnerability with increasing % forest (land-cover change)